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USPC ..... 192/84.92; 475/150

See application file for complete search history.

- (71) Applicant: **Dana Automotive Systems Group, LLC**, Maumee, OH (US)

- (72) Inventors: **Mitchell R. Lawson**, Perrysburg, OH (US); **Julius L. Jones**, Toledo, OH (US); **Rick C. Sigmon**, Perrysburg, OH (US)

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- (21) Appl. No.: 14/150,064

*Primary Examiner* — Richard Lorence

- (22) Filed: **Jan. 8, 2014**

(74) *Attorney, Agent, or Firm* — Marshall & Melhorn, LLC

- (65) **Prior Publication Data**

- (57) **ABSTRACT**

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### Related U.S. Application Data

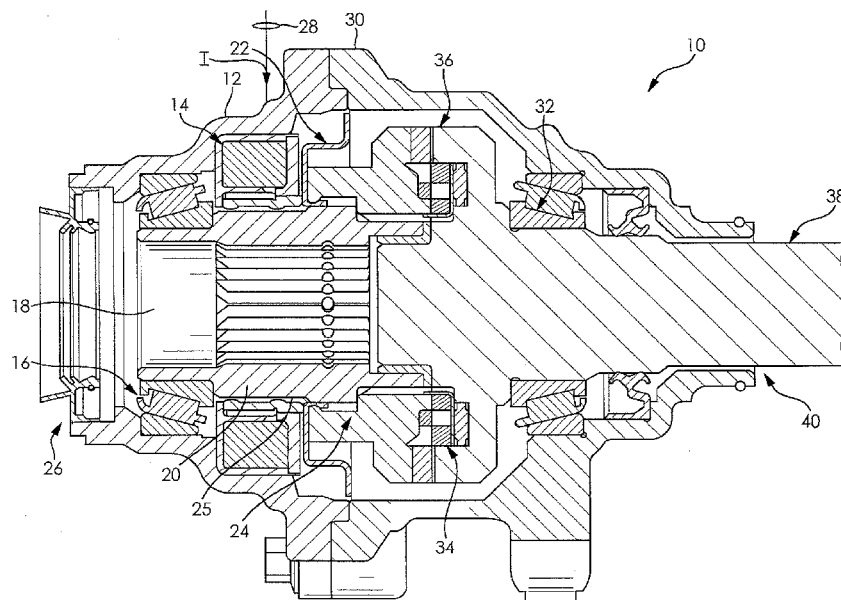
- (60) Provisional application No. 61/750,597, filed on Jan. 9, 2013, provisional application No. 61/750,683, filed on Jan. 9, 2013.

- (51) **Int. Cl.**  
**F16D 27/118** (2006.01)  
**F16D 11/00** (2006.01)

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CPC ..... *F16D 27/118* (2013.01); *F16D 2011/006*  
(2013.01); *Y10T 29/49826* (2015.01)

An electromagnetic disconnect system has an output housing having an armature with a coil and an output shaft bearing fixed to it. A pressure plate and a sliding dog clutch are slidably attached to an output shaft that is in rotational contact with the output shaft bearing. This system further has an input housing attached to the output housing. The input housing has an input shaft bearing fixed to it. The electromagnetic disconnect system further has a disengagement spring and an axially fixed dog clutch rigidly attached to an end of an input shaft that is axially disposed through an opening in the input housing and in rotational contact with the input shaft bearing.

**4 Claims, 5 Drawing Sheets**



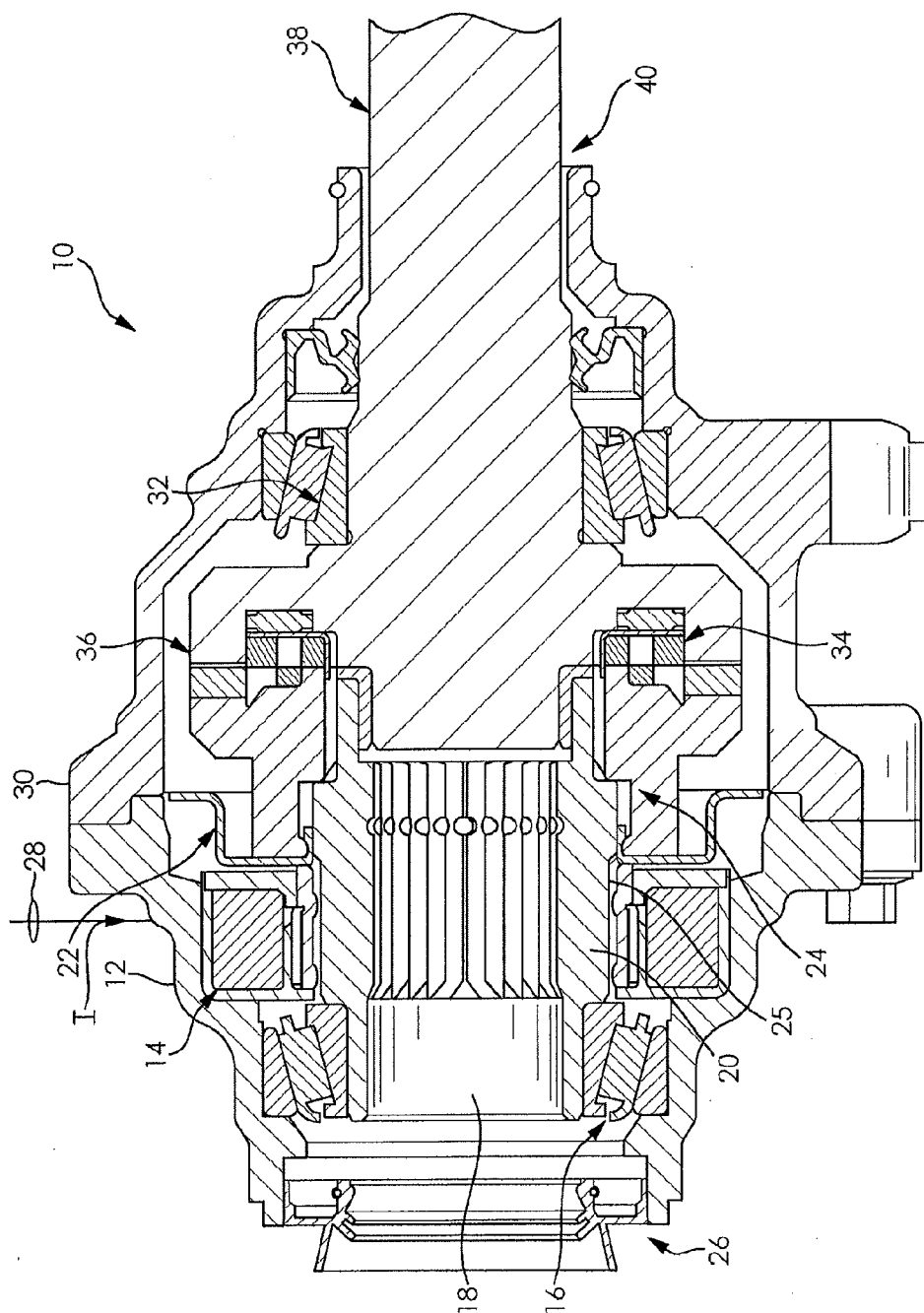


FIG. 1

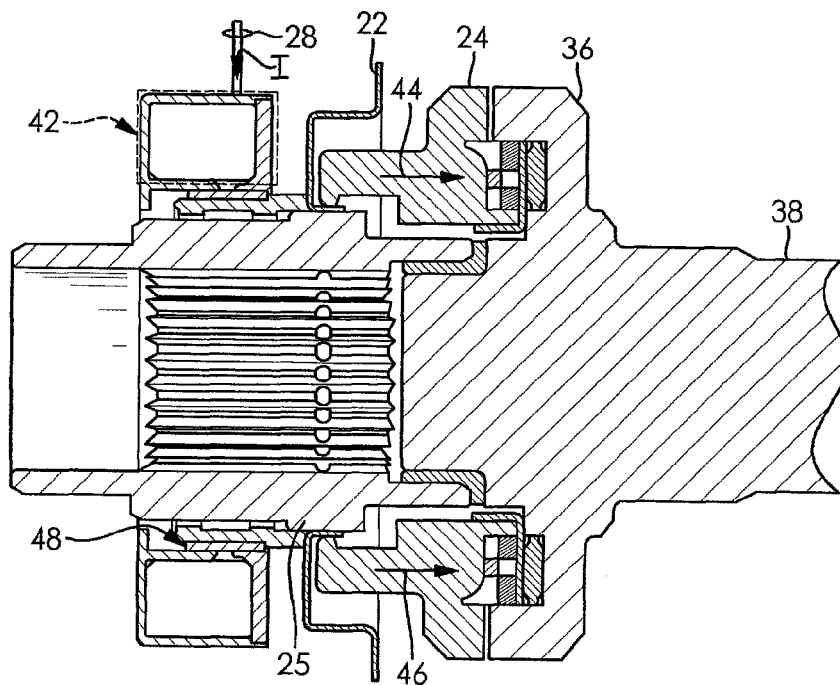


FIG. 2

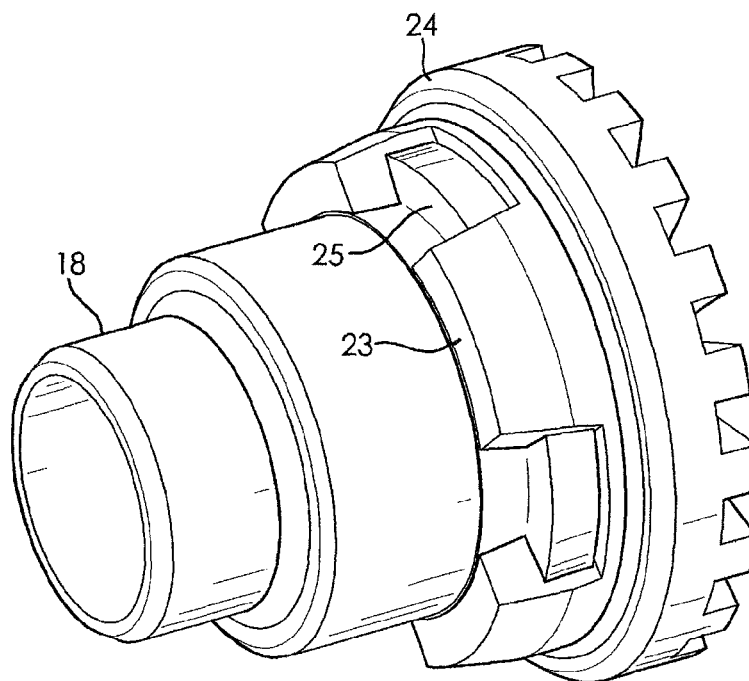
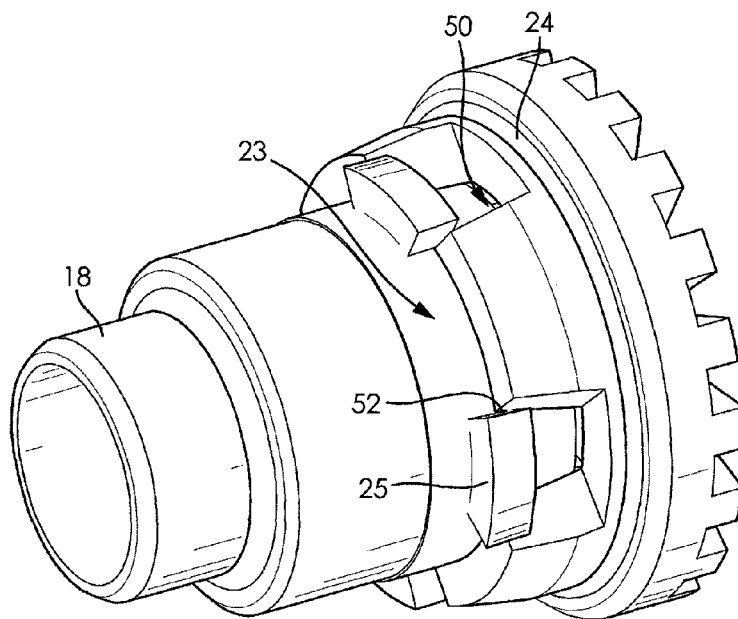
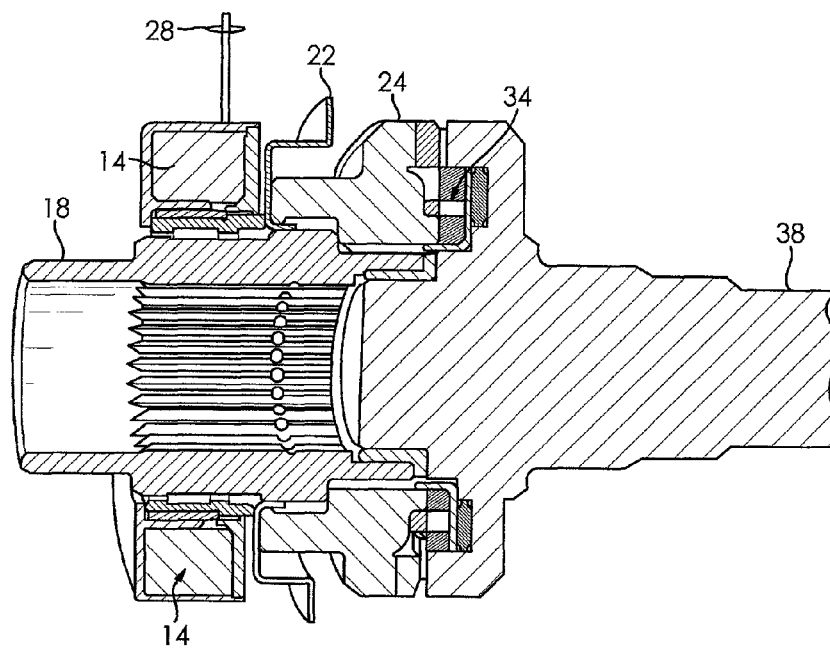


FIG. 3



**FIG. 4**



**FIG. 5**

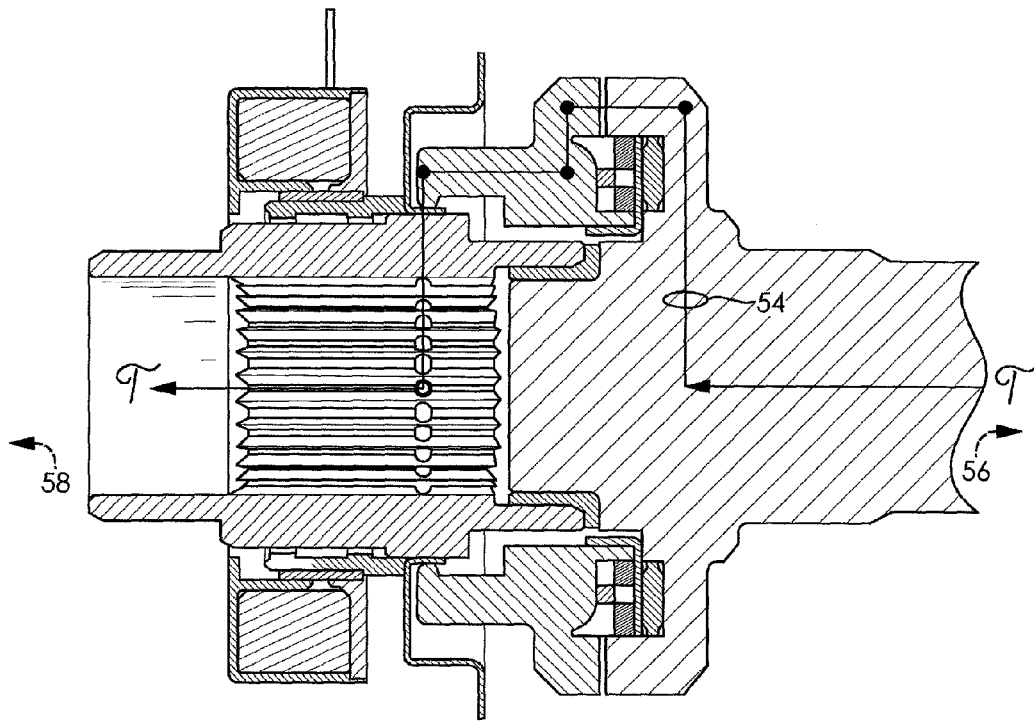
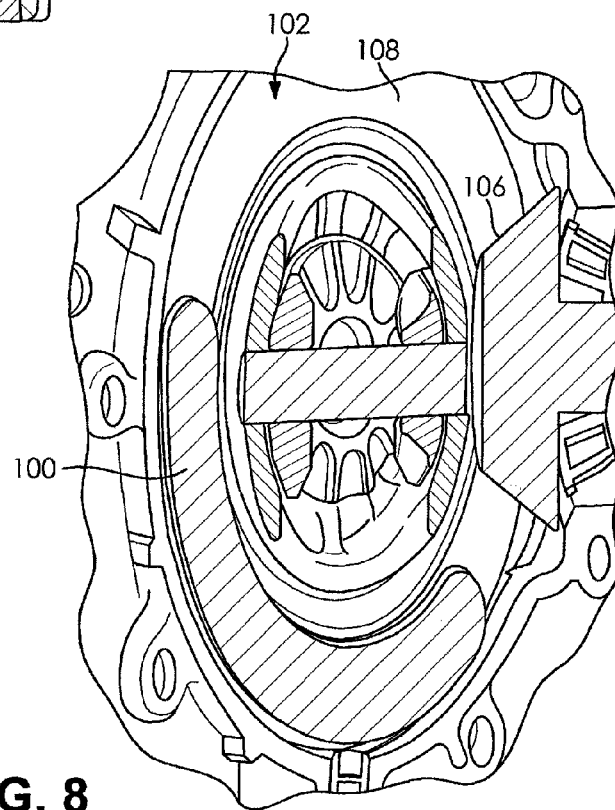
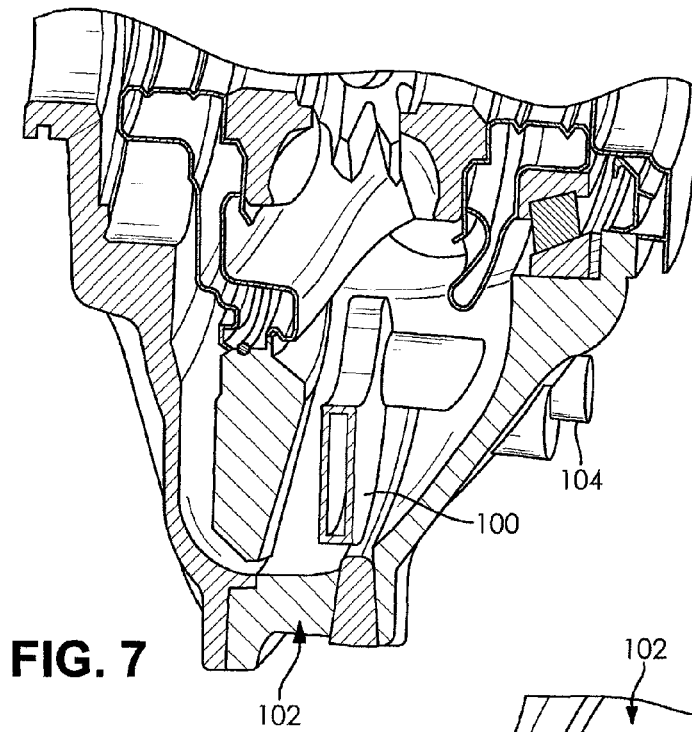


FIG. 6



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**ELECTROMAGNETIC AXLE DISCONNECT  
SYSTEM****RELATED APPLICATION**

This application claims the benefit under 35 U.S.C. §119 (e) of U.S. Provisional Patent Application Ser. No. 61/750,597, filed Jan. 9, 2013 and U.S. Provisional Patent Application Ser. No. 61/750,683, filed Jan. 9, 2013, and which are incorporated by reference herein in their entirety.

**FIELD OF THE INVENTION**

The present invention relates to connecting, locking, and disconnecting axles within a vehicle. More particularly, the present invention relates to electromagnetically connecting, mechanically securing, and disconnecting axles within a vehicle.

**BACKGROUND OF THE INVENTION**

In order to switch a vehicle between two-wheel and all-wheel drive, typically, an electromechanical actuator means is used (see, for example, U.S. Pat. No. 5,788,008 to Fort). In order to secure such a vehicle in either a two or all-drive position, often, an electronically controlled axle locking mechanism is applied to an electromechanical actuator means.

However, automotive manufacturers have new requirements for an axle disconnect system, which must disconnect the torque path from wheels to a ring gear, on request, during normal driving. In addition, noise, vibration, and harshness requirements are becoming more stringent, while response time of no more than 200 milliseconds from a time of receiving a command signal is required. Further, drag torque should be minimized across the vehicle operating speed range.

Unfortunately, conventional connecting, locking, and disconnecting axles systems, which are based on electromechanical actuators, are not capable of achieving these new requirements. In addition, the more stringent noise, vibration, and harshness requirements, and response time of no more than 200 milliseconds from a time of receiving a command signal cannot be met by conventional systems.

Consequently, what is sought is a means to achieve these new requirements without increasing the material and labor costs involved. These means need to also improve the reliability and efficiency of vehicle operations.

**SUMMARY OF THE INVENTION**

An electromagnetic disconnect system comprises an output housing having an armature with a coil and an output shaft bearing fixedly attached thereto. An output shaft has splines disposed on an end thereof, where a pressure plate and a sliding dog clutch are slidably attached to the output shaft, where the output shaft is axially disposed through an opening in the output housing and in rotational contact with the output shaft bearing. The electromagnetic disconnect system further comprises an input housing fixedly attached to the output housing. The input housing having an input shaft bearing fixedly attached thereto. The electromagnetic disconnect system further comprises a disengagement spring and an axially fixed dog clutch rigidly attached to an end of an input shaft that is axially disposed through an opening in the input housing and in rotational contact with the input shaft bearing.

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When the coil is energized, the armature with coil slidably moves the pressure plate and sliding dog clutch into engagement with the axially fixed dog clutch, thereby allowing rotational torque from the input shaft to be transferred to the output shaft.

When transferring torque from the input to output shaft, the cams on the output shaft provide a self-locking force which allows the force applied to the movable clutch member to be reduced or eliminated.

When the coil is de-energized, the disengagement spring disengages the pressure plate, sliding dog clutch, and armature from the axially fixed dog clutch, thereby disengaging rotational torque from the input shaft to be transferred to the output shaft.

Further objects and advantages of the present invention will be apparent from the following description and appended claims, reference being made to the accompanying drawings forming a part of a specification, wherein like reference characters designate corresponding parts of several views.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a cross sectional view of an electromagnetic disconnect system in accordance with the present invention;

FIG. 2 is a partial cross sectional view of the electromagnetic disconnect system of FIG. 1 at the start of engagement;

FIG. 3 is a perspective view of a dog clutch of the electromagnetic disconnect system of FIG. 1 in a disengaged position;

FIG. 4 is a perspective view of the dog clutch of FIG. 3 in an engaged position;

FIG. 5 is a partial cross sectional view of the electromagnetic disconnect system of FIG. 1 in disengagement;

FIG. 6 is a partial cross sectional view of the electromagnetic disconnect system of FIG. 1 showing torque flow;

FIG. 7 is a cross sectional view of a differential case having a heat exchanger in accordance with the present invention; and

FIG. 8 is a cross sectional view through the heat exchanger of FIG. 7.

**DESCRIPTION OF THE INVENTION**

It is to be understood that the invention may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions, directions or other physical characteristics relating to the embodiments disclosed are not to be considered as limiting, unless the claims expressly state otherwise.

FIG. 1 illustrates an electromagnetic disconnect system 10 in a mechanically disengaged position that comprises an output housing 12 having an armature 48 with a coil 14 and an output shaft bearing 16, where the coil 14 and the output shaft bearing 16 are fixedly attached thereto. An output shaft 18 has splines 20 disposed on end thereof, where a pressure plate 22 and a sliding dog clutch 24 are slidably attach to output shaft 18. The output shaft 18 is axially disposed through an opening 26 in the output housing 12, and in rotational contact with the output shaft bearing 16. The electromagnetic disconnect system 10 further comprises an input housing 30 fixedly attached to the output housing 12. The input housing 30 having an input shaft bearing 32 fixedly attached thereto. The electromagnetic disconnect system 10

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further comprises a disengagement spring **34** and an axially fixed dog clutch **36**, both of which are rigidly attached to an input shaft **38** that is axially disposed through an opening **40** in the input housing **30** and in rotational contact with the input shaft bearing **32**.

When the armature **48** with the coil **14** is energized by way of current **I** in wiring **28**, the pressure plate **22** and sliding dog clutch **24** are slidably moved into mechanical engagement with the axially fixed dog clutch **36**, thereby allowing rotational torque from the input shaft **38** to be transferred to the output shaft **18**.

When the sliding dog clutch and fixed clutch are engaged, torque is transferred thru the cams on the sliding dog clutch to the cams on the output shaft. This transfer of torque produces an axial force securing the sliding clutch member in place.

When the armature **48** with the coil **14** is de-energized, the disengagement spring **34** disengages the pressure plate **22** and sliding dog clutch **24** from the axially fixed dog clutch **36**, thereby not allowing rotational torque from the input shaft **38** to be transferred to the output shaft **18**.

FIG. 2 illustrates the flux path **42** around the armature **48** with coil **14**, when the electrical current **I** is conducted through the wiring **28** into the armature **48** with the coil **14**, at the start of engagement. Hence, the armature **48** with the coil **14** moves the pressure plate **22** and sliding dog clutch **24** toward the axially fixed dog clutch **36**, as shown by the arrows **44**, **46**.

FIG. 3 illustrates the sliding dog clutch **24** in the disengaged position, where output shaft cams **25** are seated in the sliding dog clutch cams **23**. FIG. 4 illustrates the sliding dog clutch **24** in the engaged position, where angled **50** portion of the sliding dog clutch cams **23** have slid away from the angled **52** portion of the output shaft cams **25** so as that the sliding dog clutch **24** can contact the axially fixed dog clutch **36**, in order to transfer torque from the input shaft **38** to the output shaft **18** and provide self-locking action.

FIG. 5 illustrates the electromagnetic disconnect system **10** in disengagement where the de-energized armature **48** with the coil **14**, in cooperation the disengagement spring **34**, causes the pressure plate **22** and sliding dog clutch to disengage the axially fixed dog clutch **36**. FIG. 6 illustrates a flow diagram of a torque path **54**, where the torque **T** from a vehicle side gear **56** (not shown but common in the art) is transferred to a vehicle axle shaft **58**, **56** (not shown but common in the art).

The present invention electromagnetic disconnect system **10** is capable of achieving new requirements imposed on vehicle axle systems by automotive manufacturers. These requirements involve more stringent noise, vibration, and harshness requirements, response time of no more than 200 milliseconds from a time of receiving a command signal, which conventional electromechanical systems cannot meet. It has been found that the electromagnetic disconnect system **10** achieves these new requirements without increasing the material and labor costs involved. Further, the electromagnetic disconnect system **10** improves the reliability of vehicle operations.

In addition, FIGS. 7 and 8 illustrate a heat exchanger **100**, which may be banana shaped, that is embedded in oil that is contained in a differential case **102**. Cooling fluid flows into and out of the heat exchanger **100** by way of tubing **104**, thereby cooling the oil with in the differential case **102**.

FIG. 8 shows a pinion gear **106** that would be in meshing contact with a ring gear **108**. As the cooling fluid flows in and out of the heat exchanger **100**, heat is transferred from the hot oil to the cooling fluid, which conducts the heat outside of the differential case **102**. Thereby, allowing various gears within

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the differential case **102** to operate properly and assure long term reliability for the differential **102**.

The heat exchanger structure **100** can be applied to the axle output housing **12** of the above-described electromagnetic disconnect system **10** of FIG. 1.

The following physical characteristics of Tables 1 and 2, associated with the heat exchanger structure **100**, make it novel over other heat exchanger structures.

TABLE 1

Calculation at hot temperatures:	
Coolant type:	50/50
Coolant temperature:	145° C.
Coolant flow rate:	71/min
Oil type:	ATF Dexron 3
Oil flow rate	20 l/min flowing inside the HX with a homogeneous distribution in across flow direction (i.e., perpendicular to the coolant flow)
Calculated heat transfer	648.3 W

TABLE 2

Axle Oil Heat Exchanger size:	
Arc length:	153 mm from fitting to fitting
Height:	15 mm
Width:	22 mm
Calculation at cold start:	
Coolant type:	50/50
Coolant temperature:	60° C.
Coolant flow rate:	71/min
Oil type:	ATF Dexron 3
Oil flow rate	20 l/min flowing inside the HX with a homogeneous distribution in across flow direction (i.e., perpendicular to the coolant flow)
Calculated heat transfer	259.6 W

In accordance with the provisions of the patent statutes, the principles and modes of operation of this invention have been described and illustrated in its preferred embodiments. However, it must be understood that the invention may be practiced otherwise than specifically explained and illustrated without departing from its spirit or scope.

What is claimed is:

1. A vehicle axle electromagnetic disconnect system, comprising:

an output housing having an armature with a coil and an output shaft bearing, the coil and the output shaft bearing fixedly attached to the output housing;

an output shaft having splines and angled cams disposed on an end thereof;

a pressure plate in contact with the armature;

a sliding dog clutch having angled cams, slidably attached to the output shaft angled cams, and the output shaft axially disposed through an opening in the output housing and in rotational contact with the output shaft bearing;

an input housing fixedly attached to the output housing, the input housing having an input shaft bearing fixedly attached thereto;

a disengagement spring; and

an axially fixed dog clutch rigidly attached to an end of an input shaft that is axially disposed through an opening in the input housing and in rotational contact with the input shaft bearing;



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wherein, the coil is energized with rotational torque from the input shaft to the output shaft present, the output shaft cams are unseated within the sliding dog angled cams by the armature and the pressure plate, thus the sliding dog clutch is in slidable mechanical engagement with the axially fixed dog clutch and the output shaft cams self-lock a transfer of the input shaft rotational torque to the output shaft; and

wherein, the coil is de-energized to seat the sliding dog angled cams within the output shaft angled cams, to disengage the armature and the pressure plate by way of the disengagement spring, and no longer transfer rotational torque from the input shaft to the output shaft.

2. The vehicle axle electromagnetic disconnect system of claim 1, wherein the vehicle axle electromagnetic disconnect system has a response time of no more than 200 milliseconds along a torque path from wheels to a ring gear, during normal driving conditions, from a received start command signal, so as to switch a vehicle between two-wheel and all-wheel drive.

3. A method of forming operating a vehicle axle electromagnetic disconnect system, comprising:

providing a coil and an output shaft bearing fixedly attached to an output housing;

providing a pressure plate, in contact with an armature, slidably attached to an output shaft having splines disposed on an end thereof;

providing a sliding dog clutch, with angled cams, slidably attached to the output shaft, wherein the output shaft has angled cams slidably attached to the sliding dog clutch angled cams;

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axially disposing the output shaft through an opening in the output housing, wherein the output shaft is in rotational contact with the output shaft bearing;

providing an input housing fixedly attached to the output housing;

providing an input shaft bearing fixedly attached to the input housing;

providing a disengagement spring and an axially fixed dog clutch rigidly attached to an end of an input shaft that is axially disposed through an opening in the input housing and that is in rotational contact with the input shaft bearing;

energizing the coil, with rotational torque from the input shaft to the output shaft being present, thereby moving the armature and the pressure plate and unseating the output shaft cams within the sliding dog angled cams, placing the sliding dog clutch in slidable mechanical engagement with the axially fixed dog clutch and self-locking transferring rotational torque from the input shaft to the output shaft by the output shaft cams; and

de-energizing the coil, for seating the sliding dog angled cams within the output shaft angled cams, disengaging the armature and the pressure plate by way of the disengagement spring, and no longer transferring rotational torque from the input shaft to the output shaft.

4. The method of operating the vehicle axle electromagnetic disconnect system of claim 3, further comprising transferring a torque path from wheels to a ring gear during normal driving conditions, in no more than 200 milliseconds, from a received start command signal, thereby switching a vehicle between two-wheel and all-wheel drive.

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